Implication of $\sin 2\beta$ from global fit and $B \to J/\psi K_S$

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Abstract

The measurement of $\sin 2\beta$ is discussed within and beyond the standard model. In the presence of new physics, the angle β extracted from the global fit(denoted by β_{fit}^{SM}) and the one extracted from $B \to J/\psi K_S$ (denoted by $\beta_{J/\psi}$) are in general all different from the 'true' angle β which is the weak phase of CKM matrix element V_{td}^*. Possible new physics effects on the ratio $R_\beta = \sin 2\beta_{J/\psi} / \sin 2\beta_{fit}^{SM}$ is studied and parameterized in a most general form. It is shown that the ratio R_β may provide a useful tool in probing new physics. The experimental value of R_β is obtained through an update of the global fit of the unitarity triangle with the latest data and found to be less than unity at 1σ level. The new physics effects on R_β from the models with minimum flavor violation (MFV) and the standard model with two-Higgs-doublet (S2HDM) are studied in detail. It is found that the MFV models seem to give a relative large value $R_\beta \geq 1$. With the current data, this may indicate that this kind of new physics may be disfavored and alternative new physics with additional phases appears more relevant. As an illustration for models with additional phase beyond CKM phase, the S2HDM effects on R_β are studied and found to be easily coincide with the data due to the flavor changing neutral Higgs interaction.

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I. INTRODUCTION

Recently, the BaBar and Belle Collaborations have reported their new results on the measurements of time dependent CP asymmetry $\mathcal{A}_{CP}$ of decay mode $B \to J/\psi K_S$. The definition of $\mathcal{A}_{CP}$ is given as follows

$$\mathcal{A}_{CP}(t) = \frac{\Gamma(\bar{B}^0(t) \to J/\psi K_S) - \Gamma(B^0(t) \to J/\psi K_S)}{\Gamma(\bar{B}^0(t) \to J/\psi K_S) + \Gamma(B^0(t) \to J/\psi K_S)} \equiv -\sin 2\beta_{J/\psi} \sin(\Delta m_B t). \tag{1}$$

In the framework of the Standard Model (SM), the angle $\beta_{J/\psi}$ is expected to be equal to the angle β which concerns the weak phase of Cabbibo-Kabayashi-Maskawa (CKM) matrix element V_{td}^*

$$\beta \equiv -arg\left(\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right) \tag{2}$$

which is also one of the angles of the unitarity triangles containing d and b quarks. The new measurements give the following values [1,2]:

$$\begin{aligned} \sin 2\beta_{J/\psi}|_{exp} &= 0.59 \pm 0.14 \pm 0.05 \quad \text{(BaBar)} \\ \sin 2\beta_{J/\psi}|_{exp} &= 0.58^{+0.32+0.09}_{-0.34-0.1} \quad \text{(Belle)}. \end{aligned} \tag{3}$$

Combining with the ones measured earlier by CDF and ALEPH Collaboration $0.79^{+0.41}_{-0.44}$ [3], and $0.84^{+0.82}_{-1.04} \pm 0.16$ [4], one arrives at the new world average value of $\sin 2\beta$

$$\sin 2\beta_{J/\psi}|_{exp} = 0.59 \pm 0.14. \tag{4}$$

Although this result is consistent with the prediction of Standard Model (SM), the results from BaBar and Belle may imply a possibility that the angle $\beta_{J/\psi}$ measured directly from the time dependent CP asymmetry may be different than the one from the global fit in SM (denoted by β_{fit}^{SM}) which contains the indirect CP violations of both neutral K and B meson mixings. This possibility has aroused many discussions in the literatures [5–10,53,54]. As has been pointed out in Ref. [8], a lower value of $\sin 2\beta$ less than 0.5 may imply that some hadronic parameters are out of the reasonable range. It may imply a large bag parameter $\hat{B}_K$ for the matrix element $< K^0|H_W|\bar{K}^0 >$, a large $SU(3)$ breaking factor between B^0 and B_s^0 or a small value of $|V_{ub}|$. In the SM, a lower bound of $\sin 2\beta$ can be derived from the evaluation of ϵ_K and Δm_B, a conservative bound was found to be $\sin 2\beta > 0.42$ [9] which is compared with 0.34 in [10] due to the use of different values of hadronic parameters. The existence of a lower bound on $\sin 2\beta$ also holds for new physics models with minimal flavor violation (MFV), namely a class of models which has no new flavor changing operators beyond those in the SM and no additional weak phases beyond the CKM phase.

In the SM, the angle β_{fit}^{SM} extracted from the global fit should be the same as the one measured from the time dependent CP asymmetry in the decay $B \to J/\psi K_S$. However, if there exists new physics beyond the SM, the situation may be quite different, the angle "β" extracted from two different approaches are in general not equal. This is because ϵ_K and Δm_B as well as $B \to J/\psi K_S$ will receive contributions from new physics in a quite different

manner comparing to the ones from the SM. As a consequence, the extracted "β" from two ways will become different. In the most general case, one may find that $\beta_{fit}^{SM} \neq \beta_{J/\psi} \neq \beta$ when new physics exists and the ratio

$$R_\beta \equiv \frac{\sin 2\beta_{J/\psi}}{\sin 2\beta_{fit}^{SM}} \tag{5}$$

is therefore not equal to unity. It will be shown in detail below that the true angle β may not be directly obtained from the measurement of β_{fit}^{SM} or $\beta_{J/\psi}$.

It is obvious that the deviation from $R_\beta = 1$ provides a clean signal of new physics. While the different new physics models may modify its value in different ways. In the definition of R_β, the value of $\sin 2\beta_{J/\psi}$ is model dependent, the prediction of $\sin 2\beta_{J/\psi}$ may vary largely from different new physics models. On the other hand, even when $\sin 2\beta_{fit}^{SM}$ is extracted via the same formulae as the ones in the SM and its value only depends on the hadronic parameters and the experimental data, namely it looks like model independent, but possible existence of new physics implies that β_{fit}^{SM} may not be necessarily equal to the true β in the SM. This is because the experimental data should contain all contributions from both SM and beyond the SM if new physics truly exists. Thus the relation between β_{fit}^{SM} and β depends on models. In this paper, we present a general parameterization for possible new physics contributions to R_β. For a detailed consideration, we investigate two interesting and typical models, one is the model with MFV and another is the simplest extension of SM with just adding one Higgs doublet. For convenience of mention in our following discussions, we may call such a minimal extension of the standard model with two Higgs doublet as an S2HDM [11–17], in which CP violation could solely originate from the Higgs potential [18,15,16]. The experimental value of R_β is obtained from an update of the global fit for the unitarity triangle (UT). It will be seen that the ratio R_β may provide a useful tool for probing new physics. The current data lead to a low value of R_β which is not likely to be accommodated by the models with MFV. If the future experiments confirm such a low value of R_β, the models involving new interactions with additional phases beyond the CKM phase will be preferred. Taking the S2HDM as an example, we illustrate that the new physics models with additional CP phases can easily explain the current data.

This paper is organized as follows: in section **II**, the ratio R_β with possible new physics effects is introduced and the new physics effects on R_β are parameterized in a most general form. In section **III**, the profile of the unitarity triangle is updated with the latest data and the resulting value of R_β is obtained. The new physics effects of the models with MFV and the S2HDM are discussed in section **IV**. Our conclusions are made in the last section.

II. NEUTRAL MESON MIXING WITHIN AND BEYOND THE SM

In the study of quark mixing and CP violation, it is convenient to use the Wolfenstein parameterization [20] in which the CKM matrix elements can be parameterized by four parameters λ, A, ρ and η. The unitarity relation

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \tag{6}$$

can be depicted as a closed triangle in the ρ, η plane (see Fig.1). The two sides of the triangle can be written as:

$$\hat{R}_u \equiv -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} = R_u e^{i\gamma} = \sqrt{\bar{\rho}^2+\bar{\eta}^2}e^{i\gamma},$$
$$\hat{R}_t \equiv -\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = R_t e^{-i\beta} = \sqrt{(1-\bar{\rho})^2+\bar{\eta}^2}e^{-i\beta}, \tag{7}$$

with $\bar{\rho} \equiv (1-\frac{\lambda^2}{2})\rho$, and $\bar{\eta} \equiv (1-\frac{\lambda^2}{2})\eta$. The three angles of α, β and γ of the triangle are defined as follows

$$\sin 2\alpha = \frac{2\bar{\eta}(\bar{\eta}^2+\bar{\rho}^2-\bar{\rho})}{(\bar{\rho}^2+\bar{\eta}^2)((1-\bar{\rho})^2+\bar{\eta}^2)},$$
$$\sin 2\beta = \frac{2\bar{\eta}(1-\bar{\rho})}{(1-\bar{\rho})^2+\bar{\eta}^2},$$
$$\sin 2\gamma = \frac{2\bar{\rho}\bar{\eta}}{\bar{\rho}^2+\bar{\eta}^2}, \tag{8}$$

with $\alpha+\beta+\gamma = 180^\circ$. One of the important goals in the modern particle physics is to precisely determine those angles and to test the unitarity relation of Eq.(6). Many efforts have been done for that purpose and the current data have constrained the apex of the triangle in a small region. For example, the values of λ, $|V_{cb}|$ and $|V_{ub}|$ are extracted from the semileptonic K and B decays. Besides the semileptonic decays, the important constraint may come from the neutral meson mixings, such as $K^0-\bar{K}^0$ and $B^0_{(s)}-\bar{B}^0_{(s)}$ mixings.

There are two important observables in neutral meson mixings: the indirect CP violating parameter ϵ_K of kaon and the mass difference of neutral B meson $\Delta m_{B_{(s)}}$. In the SM, their expressions read

$$\epsilon_K^{SM} = \left\{\bar{\eta}\left[(1-\bar{\rho})A^2\eta_2 S_0(x_t)+P_\epsilon\right]A^2\hat{B}_K C_\epsilon\right\}e^{i\frac{\pi}{4}}$$
$$\Delta m_{B_{(s)}}^{SM} = \frac{G_F^2}{6\pi^2}m_W^2 m_{B_{(s)}}\left(f_{B_{(s)}}\sqrt{B_{(s)}}\right)^2\eta_B S_0(x_t)|\lambda_t^{B_{(s)}}|^2. \tag{9}$$

where $S_0(x_i)$ with $(x_i = m_i^2/M_W^2)$ are the integral function arising from the box diagram [22] and η_is are the QCD corrections with the values [23] $\eta_1 = 1.38\pm0.20$, $\eta_2 = 0.57\pm0.01$, $\eta_3 = 0.47\pm0.04$ and $\eta_B = 0.55\pm0.01$, $G_F = 1.16\times10^{-5}$ GeV^{-2} is the Fermi coupling constant, f_B and B_K, B are the decay constant and bag parameter for kaon and B meson respectively. The two constants C_ϵ and P_ϵ have the values [9,10]:

$$C_\epsilon = G_F^2 F_K^2 m_K m_W^2 \lambda^{10}/(6\sqrt{2}\pi^2\Delta m_K) = 0.01$$

and

$$P_\epsilon = \left[\eta_3 S_0(x_c,x_t)-\eta_1 S_0(x_c)\right]/\lambda^4 = 0.31\pm0.05$$

In the global SM fit of UT, one usually assumes that the SM is fully responsible for the observed experimental data. This scenario, however may be invalid if there are new contributions beyond the SM. If new physics effects exist, then $\epsilon_K^{exp.} \neq \epsilon_K^{SM}(\bar{\rho},\bar{\eta})$ and $\Delta m_B^{exp} \neq \Delta m_B^{SM}(\bar{\rho},\bar{\eta})$. In general, one may write

$$\epsilon_K^{exp.} = \epsilon_K^{SM}(\bar{\rho},\bar{\eta})[1+\delta\epsilon_K] \equiv \epsilon_K^{SM}(\bar{\rho}_{fit}^{SM},\bar{\eta}_{fit}^{SM})$$
$$\Delta m_B^{exp} = \Delta m_B^{SM}(\bar{\rho},\bar{\eta})[1+\delta m_B] \equiv \Delta m_B^{SM}(\bar{\rho}_{fit}^{SM},\bar{\eta}_{fit}^{SM})[1+\delta\tilde{m}_B] \tag{10}$$

where $\delta\epsilon_K$ and δm_B ($\delta\tilde{m}_B$) represent possible new physics contributions. Therefore the parameters ρ and η extracted from the fit are in general the effective ones which may significantly deviate from their true values in the SM . The effective values ρ_{fit}^{SM} and η_{fit}^{SM} are defined as follows:

$$\epsilon_K^{exp} = \left\{\bar{\eta}_{fit}^{SM}\left[(1-\bar{\rho}_{fit}^{SM})A^2\eta_2 S_0(x_t)+P_\epsilon\right]A^2\hat{B}_K C_\epsilon\right\}e^{i\frac{\pi}{4}}$$
$$\Delta m_B^{exp}/[1+\delta\tilde{m}_B] = \frac{G_F^2}{6\pi^2}(1-\frac{\lambda}{2})^2 A^2\lambda^4 m_W^2 m_B\left(f_B\sqrt{B}\right)^2\eta_B S_0(x_t)\left((1-\bar{\rho}_{fit}^{SM})^2+(\bar{\eta}_{fit}^{SM})^2\right). \quad (11)$$

where, ϵ_K^{exp} and Δm_B^{exp} are the values measured from the experiments [31]. It is seen that in the existence of unknown new physics, one may even not be able to extract the effective parameters $\bar{\rho}_{fit}^{SM}$ and $\bar{\eta}_{fit}^{SM}$ from the data ϵ_K^{exp} and Δm_B^{exp}. Only when the new physics contributions to the term $\delta\tilde{m}_B$ are neglected, the two effective parameters $\bar{\rho}_{fit}^{SM}$ and $\bar{\eta}_{fit}^{SM}$ can be determined from the data ϵ_K^{exp} and Δm_B^{exp}. In our following fit, due to the large uncertainties in both theoretical parameters and the present data, we actually take $\delta\tilde{m}_B = 0$ as an approximation, so that the angle β_{fit}^{SM} can be extracted via the same form as the one in Eq.(8)

$$\sin 2\beta_{fit}^{SM} \equiv \frac{2\bar{\eta}_{fit}^{SM}(1-\bar{\rho}_{fit}^{SM})}{(1-\bar{\rho}_{fit}^{SM})^2+(\bar{\eta}_{fit}^{SM})^2}, \quad (12)$$

From Eq.(12) , by eliminating $S_0(x_t)$ in the expression for ϵ_K and Δm_B, the following relation holds

$$\sin 2\beta_{fit}^{SM} = C_K\left(1-\omega\bar{\eta}_{fit}^{SM}\right). \quad (13)$$

with $C_K = \frac{G_F^2 m_B m_W^2 F_B^2 B_B \eta_B|\epsilon_K|}{6\pi^2\Delta m_B A^4\hat{B}_K\eta_2 C_\epsilon}$ and $\omega = C_\epsilon A^2\hat{B}_K P_\epsilon/|\epsilon_K|$.

Before proceeding, we would like to emphasize that even if taking the expressions satisfying the same relations as the ones in the SM, it is clear that the resulting values for ρ_{fit}^{SM} and η_{fit}^{SM} are not necessary to be the true ones in the SM if new physics beyond the SM truly exists. In general, one has $\rho_{fit}^{SM} \neq \rho$ and $\eta_{fit}^{SM} \neq \eta$. Only when there are no new physics contributions to the $K^0-\bar{K}^0$ and $B^0-\bar{B}^0$ mixings, i.e. $\epsilon_K^{exp} = \epsilon_K^{SM}$ and $\Delta m_B^{exp} = \Delta m_B^{SM}$, one can then get the true values $\bar{\rho}_{fit}^{SM} = \bar{\rho}$ and $\bar{\eta}_{fit}^{SM} = \bar{\eta}$. Thus the fit can really probe the true value of $\sin 2\beta$. However, if there exists new physics beyond the SM, the relation between $\sin 2\beta_{fit}^{SM}$ and $\sin 2\beta$ will become complicated and depend strongly on new physics models, which can explicitly be seen below. Note that the values of ρ_{fit}^{SM} and η_{fit}^{SM} fitted in such a way remain model independent though they may not be equal to the true values of ρ and η in the SM.

It is noticed that in the SM neutral meson mixings only occur at loop level, new physics contributions are expected to be considerable. If we denote the transition matrix element $<f^0|H_{eff}|\bar{f}^0>$ of neutral meson $f^0(f^0 = K^0, B^0_{(s)})$ by M_{12}^f, then the new physics effects on M_{12}^f can be parameterized in the following general form:

$$M_{12}^f = \sum_{i,j=c,t}\lambda_i^f\lambda_j^f M_{12,ij}^{SM,f}(1+r_{ij}^f)+\tilde{M}_{12}^f \quad (14)$$

where $\lambda_i^f(i=c,t)$ are the products of CKM matrix elements with the definitions $\lambda_i^K \equiv V_{id}^*V_{is}$, $\lambda_i^B \equiv V_{id}^*V_{ib}$, and $\lambda_i^{B_s} \equiv V_{is}^*V_{ib}$. The matrix elements $M_{12,ij}^{SM,f}$ are the ones in SM.

They receive contributions from the internal tt, cc and ct quark loops in the box diagrams which are responsible for the $f^0 - \bar{f}^0$ mixing. Real parameters r_{ij}^f reflect the possible new physics contributions to the corresponding loop diagrams, which carry no additional weak phases besides λ_{ij}^f. Models with such property include some versions of SUSY models and type I and II 2HDM. Obviously those models belong to the ones with MFV since they carry no additional phases. New physics contributions with new weak phases are all absorbed into the last term $\tilde{M}_{12}^f$. This term may arise from additional new interactions, such as the tree level Flavor Changing Neutral Current (FCNC) and the superweak-type interactions [19] as well as interacting terms with new weak phases.

In evaluating ϵ_K in kaon system, although the contribution of tt quark loop is dominant, the effects of cc and ct quark loops are not negligible. While in the calculations of the mass differences of $B_{(s)}^0$ meson, one may only consider the tt quark loop in the box diagram.

By using the Wolfenstein parameterization for CKM matrix elements and the parameterization of Eq.(14), in the presence of new physics, the expression of ϵ_K is

$$\epsilon_K = \left\{ \bar{\eta} \left[(1-\bar{\rho}) A^2 \eta_2 S_0(x_t) \left(1 + r_{tt}^K\right) + P_\epsilon (1 + r_{ct}) \right] A^2 \hat{B}_K C_\epsilon \right\} e^{i\frac{\pi}{4}} + \tilde{\epsilon}_K \tag{15}$$

with

$$\begin{aligned} r_{ct} &\equiv \frac{\eta_3 S_0(x_c, x_t) r_{ct}^K - \eta_1 S_0(x_c) r_{cc}^K}{\eta_3 S_0(x_c, x_t) - \eta_1 S_0(x_c)} \\ \tilde{\epsilon}_K &\equiv \frac{e^{i\frac{\pi}{4}}}{\sqrt{2}\Delta m_K} \mathrm{Im} \tilde{M}_{12}^K \end{aligned} \tag{16}$$

where the new physics effects with MFV have been expressed as the corrections to the integral function $S_0(x_t)$ and P_ϵ. The effects with additional phases have been absorbed into $\tilde{\epsilon}_K$. The $B_{(s)}^0 - \bar{B}_{(s)}^0$ mass difference is also modified as follows

$$\Delta m_B \simeq \left| M_{12}^B \right| = \Delta m_B^{SM} \left| 1 + r_{tt}^B \right| \left| e^{-2i\beta} + \tilde{r}^B e^{2i\phi^B} \right|. \tag{17}$$

$$\Delta m_{B_s} \simeq \left| M_{12}^{B_s} \right| = \Delta m_{B_s}^{SM} \left| 1 + r_{tt}^{B_s} \right| \left| 1 + \tilde{r}^{B_s} e^{2i\phi^{B_s}} \right|. \tag{18}$$

Where we have kept only the tt quark loop in the box diagrams, the contributions from other loops with internal cc and ct quarks are highly suppressed and can be safely neglected.

From the definition of $\mathcal{A}_{CP}$, the $\beta_{J/\psi}$ measured from the time dependent CP asymmetry will be the total phase of M_{12}^B. Thus in the presence of new physics, The angle $\beta_{J/\psi}$ extracted from the time dependent CP asymmetry $\mathcal{A}_{CP}(t)$ in decay $B \to J/\psi K_S$ is in general different from the true value β in SM. This can be seen explicitly from the following relation

$$\sin 2\beta_{J/\psi} = \frac{\sin 2\beta - \tilde{r}^B \sin 2\phi^B}{\sqrt{1 + 2\tilde{r}^B \cos 2(\phi^B + \beta) + (\tilde{r}^B)^2}}. \tag{19}$$

The usual fit of the profile of the UT has also been made under the assumption that there is no new physics beyond the SM. The angle "β_{fit}^{SM}" which is obtained from the measurement of $K^0 - \bar{K}^0$ and $B^0 - \bar{B}^0$ mixing is usually assumed to be the true angle β associated with the phase of V_{td}^*. In general, one should not make any assumption for purpose of new physics probing, since it may be greatly modified when new physics effects come into the evaluation

of ϵ_K and $\Delta m_{B_{(s)}}$. As we have discussed before even if we still use the same formulae as the ones in SM to extract the angle β, we may only get the effective values of ρ_{fit}^{SM}, η_{fit}^{SM}, and β_{fit}^{SM}. Their values may be far away from the true ones, this is because the experiment measured results for ϵ_K and $\Delta m_{B_{(s)}}$ are the total ones which actually include all possible new physics contributions if new physics truly exists.

Combining Eq.(15) and (17) and using the definition of $\sin 2\beta$ in Eq.(8), we come to the following simple relation

$$\sin 2\beta = C_K \frac{1+r_{tt}^B}{1+r_{tt}^K}\left[\left|1-\frac{\tilde{\epsilon}_K}{\epsilon_K}\right| - \omega\bar{\eta}(1+r_{ct})\right]\sqrt{1+2\tilde{r}^B\cos 2(\phi^B+\beta)+(\tilde{r}^B)^2}, \tag{20}$$

The relation between β_{fit}^{SM} and β is straight forward,

$$\sin 2\beta_{fit}^{SM} = \frac{(1-\omega\bar{\eta}_{fit}^{SM})\,\sin 2\beta}{\sqrt{1+2\tilde{r}^B\cos 2(\phi^B+\beta)+(\tilde{r}^B)^2}\,[|1-\tilde{\epsilon}_K/\epsilon_K| - \omega\bar{\eta}(1+r_{ct})]}\left(\frac{1+r_{tt}^K}{1+r_{tt}^B}\right) \tag{21}$$

To probe new physics effects, let us define the ratio R_β between the two observables $\sin 2\beta_{J/\psi}$ and $\sin 2\beta_{fit}$ as follows

$$\begin{aligned} R_\beta &= \frac{\sin 2\beta_{J/\psi}}{\sin 2\beta_{fit}^{SM}} \\ &= \frac{1+r_{tt}^B}{1+r_{tt}^K}\left[\frac{|1-\tilde{\epsilon}_K/\epsilon_K| - \omega\bar{\eta}(1+r_{ct})}{1-\omega\bar{\eta}_{fit}^{SM}}\right]\left(1-\tilde{r}^B\frac{\sin 2\phi_B}{\sin 2\beta}\right). \end{aligned} \tag{22}$$

Note that the factor $\sqrt{1+2\tilde{r}^B\cos 2(\phi^B+\beta)+(\tilde{r}^B)^2}$ in Eq.(20) and (19) cancel each other in the expression of R_β. In the SM, R_β is clearly equal to unity. From the above equation the deviation from unity due to the new physics effects can be expressed as the products of three terms: (1) The ratio of new physics corrections to the tt quark loop in the box diagram between $B^0-\bar{B}^0$ and $K^0-\bar{K}^0$ mixings. Since almost all the new physics models give similar contribution to $B^0-\bar{B}^0$ and $K^0-\bar{K}^0$ mixing, their effect may cancel in some extent. (2) The corrections to the cc and ct-quark loops in the box diagram in kaon meson as well as the ones from the additional contributions to $K^0-\bar{K}^0$ mixing which contain new CP-violating phases. The corrections from cc, ct loops are suppressed due to the small quark mass m_c if the additional contributions come from the new scalar particles such as the charged Higgs particle $H^\pm$ in some models. However, in general case, the corrections may be considerable. Although the small mass difference between K^0 and $\bar{K}^0$ has imposed a strong constraint on the real part of $\tilde{M}_{12}$, its imaginary part can still be large and result in a sizable $\tilde{\epsilon}_K$ such as the superweak-type interactions. (3) The corrections from the additional contributions to $B^0-\bar{B}^0$ with new CP-violating phases. It can be seen that the corrections depend on the product of $\tilde{r}^B$ and $\sin\phi_B$. If $\phi^B=0$ the correction to R_β disappears. This is directly related to the cancelation of the factor $\sqrt{1+2\tilde{r}^B\cos 2(\phi^B+\beta)+(\tilde{r}^B)^2}$ in the ratio R_β. Although the new physics with zero ϕ_B can affect both $\beta_{J/\psi}$ and β_{fit}, their net effect on R_β is diminished.

III. R_β AND β^{SM}_{FIT} FROM THE GLOBAL FIT

To get the value of R_β from the data, one needs to know the values of $\beta_{J/\psi}$ and β^{SM}_{fit}. Unlike the measurement of $\beta_{J/\psi}$ which is theoretically clean, the extraction of β^{SM}_{fit} seems to surfer from some uncertainties as it involves parameters with large theoretical uncertainties. There is a long time debate on the treatment of the theoretical errors. Basicly there are three different approaches [24].

(1) Assuming all the errors, both experimental and theoretical ones are the random variables which obey Gaussian distribution [26]. The most recent fitted results at $95\% CL$ are [25]:

$$-0.82 \leq \sin 2\alpha^{SM}_{fit} \leq 0.42, \;\; 0.49 \leq \sin 2\beta^{SM}_{fit} \leq 0.94, \;\; 42^\circ \leq \gamma^{SM}_{fit} \leq 83^\circ \tag{23}$$

(2) The distribution of experimental error is treated as Gaussian, but one imposes a *prior* flat distribution on the theoretical error, i.e. assuming the theoretical parameters are the random variables which are uniformly populated in some reasonable regions , then by using the Bayesian approach, the distributions of the parameters can be determined [24,27]. The recent fits using this method give the results [24]

$$-0.88 \leq \sin 2\alpha^{SM}_{fit} \leq 0.04, \;\; 0.57 \leq \sin 2\beta^{SM}_{fit} \leq 0.83, \;\; 42^\circ \leq \gamma^{SM}_{fit} \leq 67^\circ \tag{24}$$

(3) The distribution of experimental error is treated as Gaussian, but one *does not* assume any distribution on the theoretical error, since they are unknown parameters which should have a unique value. their errors should be largely deduced with the improvement of the theory and the experiments. To get a quantitative result, the space of the allowed region for the theoretical parameters are scanned. For each set of parameters a contour at some confidence level (for example 68% or 95%) is made, then the whole region enveloping all the contours is considered as the allowed region at some *overall* confidence level. Note that in doing this , the final results will have no clear probability explanation. The most recent fit gives [28,29]

$$-0.95 \leq \sin 2\alpha^{SM}_{fit} \leq 0.5, \;\; 0.5 \leq \sin 2\beta^{SM}_{fit} \leq 0.85, \;\; 40^\circ \leq \gamma^{SM}_{fit} \leq 84^\circ \tag{25}$$

In this paper, to get a more conservative conclusion, we adopt the last method and update the fit with the latest data on Δm_B and Δm_{B_s}

Let us briefly describe the method and parameters used in the fitting of the unitarity triangle (UT). The detailed description of the fitting procedure can be found in Ref. [30].

Among the four Wolfenstein parameters A, ρ, η and λ, the value of λ has been well determined with a relative high precision through semileptonic kaon decays, $K^+ \to \pi^0 e^+ \nu_e$ and $K^0_L \to \pi^- e^+ \nu_e$. In the fit, we quote the value of $\lambda = 0.2196$ [31] and take it as a fixed parameter.

The constraints on the apex of UT can be obtained from various experiments of the semileptonic B decays. In $b \to c$ transition such as $B \to X_c l \nu$ and $\overline{B^0} \to D^{*+} l^+ \bar{\nu}_e$, the value of $|V_{cb}|$ can be determined. Here we quote the value of V_{cb} from the most recent LEP results [32]

$$|V_{cb}| = (40.4 \pm 1.8) \times 10^{-3}, \quad (A = 0.850 \pm 0.037) \tag{26}$$

which is an average of measurements between inclusive and exclusive B decays. From $B \to \rho l^+ \bar{\nu}_e$ the value of $|V_{ub}|$ could be extracted. However, in the determination of V_{ub}, some model dependences have to be involved in the evaluation of the ratio $|V_{ub}/V_{cb}|$, which results in a considerable theoretical error. For a recent review of the theoretical error in determining $|V_{ub}/V_{cb}|$, we refer to the reference [35]. The recent measurements of V_{ub} from LEP and CLEO collaboration give the following values: [36,37]

$$\begin{aligned} |V_{ub}| &= (4.13^{+0.42}_{-0.47}(\text{stat.+det.})^{0.43}_{-0.48}(b \to c \text{ syst.})^{+0.24}_{-0.25}(b \to u \text{ sys.}) \\ &\quad \pm 0.02(\tau_b) \pm 0.20(\text{Model}) \times 10^{-3}.(\text{LEP}) \qquad (27) \\ |V_{ub}| &= (3.25 \pm 0.14(\text{stat.})^{+0.21}_{-0.29}(\text{syst.}) \pm 0.55(\text{model}) \times 10^{-3}.(\text{CLEO}) \qquad (28) \end{aligned}$$

Note that both the determination of $|V_{ub}|$ and $|V_{cb}|$ may still suffer from sizable theoretical uncertainties [38–40]. In the fit, we take the central value of $|V_{ub}/V_{cb}|$ as a free theoretical parameter which lies in the range

$$< V_{ub}/V_{cb} > \in [0.07, 0.1] \qquad (29)$$

and the value of $|V_{ub}|$ has the following form

$$|V_{ub}| = < V_{ub}/V_{cb} > |V_{cb}| \pm 0.14 \qquad (30)$$

It is noted that possible new physics contributions to the semileptonic bottom meson decays are in general expected to be small, the extracted CKM parameters $|V_{cb}|$ and $|V_{ub}|$ are regarded as the true ones $|V_{cb}| = A\lambda^2$ and $|V_{ub}| = \sqrt{\rho^2 + \eta^2}$.

The other important constraint comes from the measurements of ϵ_K. The expression of ϵ_K has been discussed in the previous section. From Eq.(15), the major theoretical error comes from the hadronic parameter $\hat{B}_K$, and the QCD correction η_1, and η_3. the recent lattice calculations give the result [41]

$$0.8 \leq \hat{B}_K \leq 1.1. \qquad (31)$$

The errors of η_i can be found in the previous section. There are also experimental errors on the values of c and t running quark masses,

$$\bar{m}_c(m_c) = 1.25 \pm 0.1 \text{ GeV}, \quad \bar{m}_t(m_t) = 165.0 \pm 5.0 \text{ GeV} \qquad (32)$$

The constraint of R_t could arises from both $B^0 - \bar{B}^0$ and $B^0_s - \bar{B}^0_s$ mixing. Here the parameter with a large uncertainty is $f_B\sqrt{B_B}$. In the fit, we take the value [42]

$$160 \text{ MeV} \leq f_B\sqrt{B_B} \leq 240 \text{ MeV} \qquad (33)$$

Recently, the BaBaR and Belle Collaboration has reported their first measurements on Δm_{B_d}. The combined result from the hadronic and semileptonic decays is [1,43] :

$$\begin{aligned} \Delta m_{B_d} &= 0.512 \pm 0.017(\text{stat.}) \pm 0.022(\text{syst.})\, ps^{-1} \quad (\text{BaBaR}) \\ \Delta m_{B_d} &= 0.456 \pm 0.008(\text{stat.}) \pm 0.030(\text{syst.})\, ps^{-1} \quad (\text{Belle}) \qquad (34) \end{aligned}$$

comparing with the old world average value of $0.472 \pm 0.017 ps^{-1}$ [31], the result of BaBaR is slightly higher. Now the new world average is

$$\Delta m_{B_d} = 0.478 \pm 0.013\, ps^{-1} \tag{35}$$

Besides Δm_B, the mass difference of B_s^0 and $\bar{B}_s^0$ also imposes a strong constraint on the size of R_t. It is helpful to introduce a $SU(3)$ breaking factor $\xi^2 \equiv (f_{B_s}\sqrt{B_{B_s}})^2/(f_B\sqrt{B_B})^2$, the constraint on R_t from Δm_{B_s} reads

$$R_t \leq \frac{\xi}{\lambda}\sqrt{\frac{m_{B_s}}{m_{B_d}}\frac{\Delta m_{B_d}}{\Delta m_{B_s}|_{min}}} \tag{36}$$

In the fit , we take $\xi \in [1.08, 1.2]$ [41]. The lower bound of Δm_{B_s} is now updated to $\Delta m_{B_s} > 14.9$ ps^{-1} at 95%CL [34] which is also higher than the previous value of 14.3 ps^{-1}. This bound is obtained through the so called 'amplitude method' [33]. The latest data indicate that $\Delta m_{B_s} \sim 17.7$ ps^{-1}. If this result can be confirmed by the future experiment, Δm_{B_s} will impose strong constraint on new physics models [45].

The other two important CP-violation observables are the direct CP violation parameter ϵ'/ϵ and $\sin 2\beta$ from the time dependent CP asymmetry of decay $B \to J/\psi K_S$. As the measurements of $\sin 2\beta$ and ϵ'/ϵ are now preliminary, they are not considered in our present fitting . However, it needs to emphasize that including the constraints from ϵ'/ϵ may impose a nontrivial lower bound of $\eta > 0.32$ [28]. It would be interesting to further discuss its constraint with the improved prediction for ε'/ε [46].

The basic idea of the fit is based on the least square method. The first step of the procedure is to construct a quantity χ^2 which has the following form

$$\chi^2 = \sum_i \frac{(f_i(A,\rho,\eta) - < f_i >)^2}{\sigma_i^2} \tag{37}$$

where $< f_i >$ and σ_i are the central values and corresponding errors of the experimentally measured observables. They contain $|V_{cb}|, |V_{ub}|, |\epsilon_K|, \Delta m_B$ and m_c, m_t. $f_i(A,\rho,\eta)$ are the values calculated from the theories. They are the functions of parameters A, ρ, η. The set of A, ρ, η which minimizes the χ^2 will be regarded as the best estimated values. On the determination of Δm_{B_s}, the ' amplitude method' [33] is adopted, which uses the amplitude curves measured from the experiments [34] and add a term χ_s^2 to the total χ^2:

$$\chi_s^2 = \frac{(1 - \mathcal{A}(\Delta m_{B_s}))^2}{\sigma_{\mathcal{A}}^2(\Delta m_{B_s})} \tag{38}$$

Note that there is an alternative approach to build the log-likelihood function in which one uses the values relative to the ones at $\Delta m_s = \infty$, i.e. use $[\frac{(\mathcal{A}-1)^2}{\sigma_{\mathcal{A}}^2} - \frac{\mathcal{A}^2}{\sigma_{\mathcal{A}}^2}]$ instead of $\frac{(\mathcal{A}-1)^2}{\sigma_{\mathcal{A}}^2}$ [33,24,44]. The detailed comparison between these two approaches can be found in Ref. [24]. In the fit, we choose A, ρ, η and m_c, m_t as free parameters to be fitted and scan the allowed range for the theoretical parameters $< V_{ub}/V_{cb} >$, $\hat{B}_K$, $f_B\sqrt{B_B}, \eta_s$, η_1, and η_3. For each set of theoretical parameters, a 68%(95%) CL contour which corresponds to $\chi^2 = \chi^2_{min} + 2.4(6.0)$ is made, then the region enveloping all the contours is the allowed region for ρ and η at an *overall* 68%(95%) level. As usual, a χ^2 probability cut is used to reject the contours with relative high χ^2_{min} which means that the fit is not consistent.

The fit is implemented by using the program package MINUIT [47]. The result is shown in Fig.3. From the figure, one can read off the allowed region for ρ and η. The results are

$$
\begin{aligned}
&0.09 \le \rho_{fit}^{SM} \le 0.28\,, \quad 0.23 \le \eta_{fit}^{SM} \le 0.46 \quad (at\ 68\%\ CL)\\
&0.10 \le \rho_{fit}^{SM} \le 0.30\,, \quad 0.20 \le \eta_{fit}^{SM} \le 0.49 \quad (at\ 95\%\ CL)
\end{aligned}
\tag{39}
$$

or equivalently,

$$
\begin{aligned}
&-0.89 \le \sin 2\alpha_{fit}^{SM} \le 0.37, \quad 0.56 \le \sin 2\beta_{fit}^{SM} \le 0.85, \quad 41^\circ \le \sin^2\gamma_{fit}^{SM} \le 75^\circ, \quad (at\ 68\%\ CL)\\
&-0.95 \le \sin 2\alpha_{fit}^{SM} \le 0.41, \quad 0.48 \le \sin 2\beta_{fit}^{SM} \le 0.88, \quad 38^\circ \le \sin^2\gamma_{fit}^{SM} \le 76^\circ, \quad (at\ 95\%\ CL)
\end{aligned}
\tag{40}
$$

and the range for the combination factor of the CKM matrix elements, $Im\lambda_t A^2\lambda^5\ \eta$, used in the calculation of direct CP-violating parameter ε'/ε in kaon decay [46], is given by

$$
\begin{aligned}
&0.76\times 10^{-4} \le Im\lambda_t = A^2\lambda^5\ \eta \le 1.73\times 10^{-4}\ , \quad (at\ 68\%\ CL)\\
&0.66\times 10^{-4} \le Im\lambda_t = A^2\lambda^5\ \eta \le 1.84\times 10^{-4}\ , \quad (at\ 95\%\ CL)
\end{aligned}
\tag{41}
$$

As the allowed ranges for theoretical errors which are the main sources of total errors are the same in both fits , the results at 68% and 95%CL are quite similar, It is needed to note that by using the scanning method, there is no probability explanation of the contours. One can not get the usual central value of the fitted parameters.

In the fitting, the χ^2 probability cut is set to be $Prob(\chi^2) \le 5\%$. The final results depend on the cut. We have checked that a lower cut such as 2% or 1% will give a larger allowed range, which allows the angle γ to be greater than 90°. The probability of large γ has been widely discussed in Refs.. [48] to meet the recent CLEO data on hadronic charmless B decays. However, the model independent analysis show that in general there are two solutions for γ from the charmless B decays. The one with $\gamma < 90^\circ$ and the other one with $\gamma > 90^\circ$ [49]. The data of Δm_B especially on Δm_{B_s} may strongly constrain γ to be less than 90°. From Fig.3, with the cut of 5%, there is no indication of $\gamma > 90^\circ$.

With the angle β_{fit} obtained from the above fit and the average value for $\beta_{J/\psi}$, the ratio R_β is found to be

$$
0.57 \le R_\beta^{exp.} \le 1.1 \quad (at\ 68\%\ CL)\ , \quad 0.31 \le R_\beta^{exp.} \le 1.36 \quad (at\ 95\%\ CL)
\tag{42}
$$

The present data prefer a small value of $R_\beta < 1$ at 1-σ level. If it is confirmed by the future experiments, it will of course be a signal of new physics. Further more, R_β may be used to distinguish different effects of new physics. This will be discussed in the next section.

IV. NEW PHYSICS EFFECTS ON THE RATIO R_β

The contributions of new physics to R_β depend on the models. In this section, we choose two type of new physics models to illustrate new physics effects. one of them is the model with MFV, the other is the models with new CP-violating phases, such as the S2HDM.

A. R_β in models with MFV

In a class of the models with MFV, the expression of R_β may be greatly simplified. As MFV implies that there are no new operators beyond the SM, the values of r_{tt}^B and r_{tt}^K

which come from the same internal tt quark loop in $B^0 - \bar{B}^0$ and $K^0 - \bar{K}^0$ mixings must be the same [9,10,21]. MFV also means that new CP-violating phases must vanish. Thus the following conditions hold

$$r_{tt}^B = r_{tt}^K, \quad \tilde{r}^B = 0, \quad \phi^B = 0, \quad \text{and} \quad \tilde{\epsilon}_K = 0 \tag{43}$$

Thus one has

$$\sin 2\beta_{J/\psi} = \sin 2\beta, \tag{44}$$

which shows that in this case the angle $\beta_{J/\psi}$ measured from $B \to J/\psi K_S$ is the 'true' angle β up to a four fold ambiguity. Assuming that r_{ct} is small, which is a good approximation for many models [21], the ratio R_β has the following simple form

$$R_\beta|_{MFV} = \frac{1 - \omega\bar{\eta}}{1 - \omega\bar{\eta}_{fit}^{SM}} \tag{45}$$

Since the value of $|V_{ub}|$ is extracted from the semileptonic $B \to \pi(\rho)e\nu_e$ decay dominated by the tree diagrams, it is widely believed that its value is not likely to be affected by new physics. This may result in the relation: $\bar{\rho}^2 + \bar{\eta}^2 = (\bar{\rho}_{fit}^{SM})^2 + (\bar{\eta}_{fit}^{SM})^2 = R_u^2$. Combining this relation with Eqs.(44) and (8), the values of $\bar{\rho}$ and $\bar{\eta}$ can be solved as functions of two obserbales R_u and $\beta_{J/\psi}$.

$$\bar{\rho} = R_u \cos\varphi_{\pm}, \quad \bar{\eta} = R_u \sin\varphi_{\pm}. \tag{46}$$

with $\varphi_{\pm} = \sin^{-1}(\sin\beta_{J/\psi}/R_u) \pm \beta_{J/\psi}$. Note that the solution for φ_+ corresponds to $\bar{\rho} < 0$. This is quite different from the value of $\bar{\rho}_{fit}^{SM}$ which seems be positive under the constraint from the data of $B_s^0 - \bar{B}_s^0$ mixing. If one assumes that the difference between true $\bar{\rho}$ and the fitted $\bar{\rho}_{fit}^{SM}$ caused by new physics effects is not too large, the solution for φ_+ could be ignored. Taking the value of R_u and $\sin 2\beta_{J/\psi}$, one may find at 1σ level

$$1.03 \le R_\beta|_{MFV} \le 1.36 \;\; \text{for } \varphi_- \,. \tag{47}$$

For φ_+ solution, one gets a small value for $R_\beta|_{MFV}$, i.e., $0.90 \le R_\beta|_{MFV} \le 1.21$. In obtaining these numerical values, the errors of ω and $\bar{\eta}_{fit}^{SM}$ are considered to be independent for simplicity. In general, they may be treated to be correlated as they all depend on the hadronic parameters. For a more detailed analysis, it should be interesting to include the correlation effects.

Comparing $R_\beta|_{MFV}$ with the experimental values of $R_\beta^{exp.}$ in Eq.(42) , it is found that the models with MFV prefer to give a large value of R_β which is not likely to agree with the current data. If the disagreement is confirmed by the future more precise data, all the models with MFV will be ruled out. It implies that new physics effects with flavor changing interactions beyond the CKM quark mixing must be involved to explain the data.

B. R_β in S2HDM

The S2HDM without imposing discrete symmetries [11–17,51] is a good example for models which can give nonzero value of $\tilde{\epsilon}_K, \tilde{r}^B$ and ϕ^B. In the S2HDM, the tree level flavor

changing neutral current can be induced from the scalar interactions between neutral Higgs bosons and quarks. As all the Yukawa couplings in the model are allowed to be complex, the S2HDM can give rich sources of CP violation [15,16,52]. It is not difficult to find that the values of r_{tt}^B, $\tilde{r}^B$ and ϕ^B in S2HDM are given by

$$r_{tt}^B = \frac{1}{4}\,|\xi_t|^4\, y_t \frac{\eta_{tt}^{HH}}{\eta_B} \frac{B_V^{HH}(y_t)}{B^{WW}(x_t)} + 2\,|\xi_t|^2\, y_t \frac{\eta_{tt}^{HW}}{\eta_B} \frac{B_V^{HW}(y_t, y_W)}{B^{WW}(x_t)} \tag{48}$$

$$\tilde{r}^B \sin 2\phi^B = \frac{\tilde{B_B}}{B_B} \sum_k \left(\frac{2\sqrt{3}\pi v m_B}{m_{H_k^0} m_t} \right)^2 \frac{m_d}{m_b} \frac{1}{V_{td}^2} \frac{\mathrm{Im}(Y_{k,13}^d)^2}{\eta_B B^{WW}(x_t)} \tag{49}$$

where ξ_q is the Yukawa coupling constant between charged Higgs and q quark. $B_{(V)}^{WW(HW,HH)}$ are the integral functions of the box diagrams [50] with variable $x_t = m_t^2/m_W^2$, $y_t = m_t^2/m_H^2$ and $y_W = m_W^2/m_H^2$. η_{tt}^{HH} is the QCD correction. It is seen that the value of r_{tt}^B is directly related to the coupling ξ_t. In Fig.4, r_{tt}^B is plotted as a function of the charged Higgs mass $m_{H^\pm}$ with different values of ξ_t. It can be seen that the typical value of r_{tt}^B is around 0.2. For large ξ_t , r_{tt}^B could become large.

The value of $\tilde{r}^B$ depends on the imaginary part of $Y_{k,ij}^f$ which is given by reduced Yukawa couplings between the k-th neutral Higgs boson and quarks. $\tilde{B}_B$ and B_B are the bag parameters for $(S+P)\bigotimes(S-P)$ and $(V-A)\bigotimes(V-A)$ four quark operators respectively.

Similar calculations can be made for the $K^0 - \bar{K}^0$ mixing. r_{tt}^K, r_{ct} in S2HDM are given by

$$r_{tt}^K = r_{tt}^B \tag{50}$$

$$r_{ct} = \frac{\sqrt{y_t y_c}(\frac{x_t}{x_c})\frac{1}{2}\eta_{tt}^{HH}|\xi_c\xi_t|^2 B_V^{HH}(y_c, y_t) + 4\eta_{ct}^{HW} Re(\xi_c\xi_t) B_V^{HW}(y_c, y_t, y_W)}{(\frac{x_t}{x_c})\eta_B B^{WW}(x_c, x_t) - \eta_1 B^{WW}(x_c)} \tag{51}$$

$$\tag{52}$$

Since x_t/x_c is of order $\mathcal{O}(10^4)$, r_{ct}^K can be approximately written as

$$r_{ct}^K \approx \frac{1}{2}\sqrt{y_t y_c} \frac{\eta_{tt}^{HH}}{\eta_B} \frac{B_V^{HH}(y_c, y_t)}{B^{WW}(x_c, x_t)} |\xi_c\xi_t|^2 \tag{53}$$

As the value of $\sqrt{y_t y_c}$ is of order 10^{-2} and $|\xi_c\xi_t|^2$ is typicly of order 1, one may find that r_{ct} is relatively small and of order $\mathcal{O}(10^{-2} \sim 10^{-1})$. The S2HDM contribution to $\tilde{\epsilon}_K$ is complicate, it may arise from both short and long distance interactions. The detailed discussion of $\tilde{\epsilon}_K$ can be found in Ref. [17]

If one ignores the r_{ct}^K , the ratio R_β mainly depends on the value of $\tilde{\epsilon}_K$, $ImY_{k,13}^d$ and m_{H^0} as well as the true value of $\sin 2\beta$ and $\bar{\eta}$. The ratio R_β has the following form

$$R_\beta = \frac{|1 - \tilde{\epsilon_K}/\epsilon_K| - \omega\bar{\eta}}{1 - \omega\bar{\eta}_{fit}^{SM}} \left(1 - \frac{\tilde{B_B}}{B_B} \sum_k \left(\frac{2\sqrt{3}\pi v m_B}{m_{H_k^0} m_t} \right)^2 \frac{m_d}{m_b} \frac{1}{|V_{td}^2|} \frac{\mathrm{Im}(Y_{k,13}^d)^2}{\eta_B B^{WW}(x_t)} \right) \tag{54}$$

Which shows that the new interactions between neutral Higgs and quarks are the main sources for the changing of ratio R_β. The value of R_β as the function of neutral Higgs mass

m_{H^0} is plotted in Fig.5 with different values of $ImY^d_{k,13}$ and $\tilde{\epsilon}_K/\epsilon_K$. Where for simplicity we have taken $\bar{\eta} \simeq \bar{\eta}_{fit} = 0.35$ and $\tilde{B}_B \simeq B_B$. From the figure, the value of R_β can be smaller than 1 for positive $Im(Y^d_{K,13})^2$ or $\tilde{\epsilon}_K/\epsilon_K$. Thus the present data can be easily explained in the S2HDM.

V. CONCLUSIONS

In conclusion, we have investigated the measurement of the UT angle β within and beyond the SM. It has been shown that if new physics beyond the SM truly exists, the angle β extracted from the global fit(denoted by β^{SM}_{fit}) and the one extracted from $B \to J/\psi K_S$ (denoted by $\beta_{J/\psi}$) could be in general all different from the 'true' angle β in the SM. The observable R_β, which is the ratio between the angle β measured from the time dependent CP asymmetry of decay $B \to J/\psi K_S$ and the one extracted from the global fit, is introduced and studied in detail. By using the scanning method, the value of R_β is obtained from an update of the fit of the UT with the latest data and it is found to lie in the range.

$$0.57 \leq R^{exp.}_\beta \leq 1.1 \quad (at\ 68\%\ CL)\ , \quad 0.31 \leq R^{exp.}_\beta \leq 1.36 \quad (at\ 95\%\ CL)$$

As the SM calculation gives $R_\beta = 1$, the deviation of R_β from unity is a clean signal of new physics. On the study of new physics effects, we have given a general parameterization of R_β. By using this parameterization, the effects from the models with MFV and the S2HDM have been investigated in detail. It has been found that the MFV models seem to give a large R_β relative to the current data. If it can be comfirmed by the future experiments, it will indicate that this kind of new physics are difficult to explain the small value of R_β. Such models include type I and type II 2HDM and some simple versions of SUSY. Thus new physics with additional phases should be considered. The most recent discussions on models with MFV. can also be found in Ref. [54,53] . As an illustration for those models with additional phases beyond the one in the CKM matrix element, the S2HDM effects on R_β has been studied, especially, if the superweak type contributions [19] to ϵ_K are considered, it could easily coincide with the data.

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REFERENCES

[1] B. Aubet, et al, BaBaR collaboration,hep-ex/0107013.
[2] A. Abashian et. al, Belle Collaboration, hep-ex/0102018.
[3] T.Affolder et al, CDF Collaboration, *Phys. Rev.* **D61** (2000) 072005.
[4] The ALEPH Collaboration, hep-ex/0009058.
[5] A. L. Kagan , M. Neubert, *Phys. Lett.* **B492** (2000) 115.
[6] J. P. Silva and L. Wolfenstein *Phys. Rev.* **D63** (2001) 056001.
[7] Z. Z. Xing, hep-ph/0008018.
[8] G. Eyal, Y. Nir, G. Perez, JHEP 0008(2000)028.
[9] A. J. Buras, lecture given at the 38th course of the Erice International school of subnuclear physics, hep-ph/0101336.
[10] A. J. Buras, R. Buras hep-ph/0008273.
[11] T.P.Cheng and M.Sher, Phys.Rev.**D35**,3484(1987).
[12] A. Antaramian, L.J. Hall, and A. Rasin, Phys. Rev. Lett. **69**, 1871 (1992).
[13] W.S. Hou, Phys. Lett. **B296**, 179 (1992); D.W. Chang, W.S. Hou and W.Y. Keung, Phys. Rev. **D48**, 217 (1993).
[14] L.J. Hall and S. Weinberg, Phys. Rev. **D48**, 979 (1993).
[15] Y.L. Wu and L. Wolfenstein, Phys. Rev. Lett. **73**, 1762 (1994); L. Wolfenstein and Y.L. Wu, Phys. Rev. Lett., **73**, 2809 (1994).
[16] Y.L. Wu, in: Proceedings at 5th Conference on the Intersections of Particle and Nuclear Physics, St. Petersburg, FL, 31 May- 6 Jun 1994, pp338, edited by S.J. Seestrom (AIP, New York, 1995), hep-ph/9406306; hep-ph/9404241, 1994 (unpublished).
[17] Y. L. Wu and Y. F. Zhou, *Phys. Rev.* **D61** (2000) 096001.
[18] T.D. Lee, Phys. Rev. **D8**, 1226 (1973); Phys. Rep. **9**, 143 (1974).
[19] L. Wolfenstein, *Phys. Rev. Lett.* **13** (1964) 562
[20] L. Wolfenstein, *Phys. Rev. Lett.* **51** (1983) 1945.
[21] A. J. Buras, P.Gambino, M. Gorbahn, S.Jager and L. Silvestrini , hep-ph/0007085.
[22] T. Inami, C.S.Lim, Progr. Theor. Phys. 65(1981)297.
[23] A. J. Buras, M. Jamin, and P.H . Weisz, *Nucl. Phys.* **B347** (1990) 491
[24] M. Ciuchini, et. al, hep-ph/0012308
[25] X. G. He, Y. K. Hsiao, J. Q. Shi, Y. L. Wu and Y. F. Zhou , hep-ph/0011337.
[26] A.Ali, D.London *Eur. Phys. J.***C9**(1999)687, A.Ali, D.London hep-ph/0002167.
[27] F. Caravaglios, F. Parodi, P. Roudeau and A. Stocchi hep-ph/0002171. F. Parodi, P. Roudeau and A. Stocchi, Nuovo Cim. 112A(1999)833. M.Ciuchini, et. al, *Nucl. Phys.* **B573** (2000) 201.
[28] S. Plaszczynski, M. H. Schune hep-ph/9911280.
[29] A. Falk, hep-ph/9908520. S. Stone, hep-ph/9910417. Y. Grossman, Y. Nir, S. Plaszczynski and M. H. Schune, *Nucl. Phys.* **B511** (1998) 69.
[30] The BaBar Physics Book, P.F. Harrison and H.R. Quinn eds., SLAC-R-504(1998).
[31] Particl data Group, *Eur. Phys. J.***C15**(2000)1.
[32] http://lepvcb.web.cern.ch/LEPVCB/.
[33] H.G. Moser and A. Roussarie, Nucl. Instr. and Methods A384(1997)491.
[34] http://www.cern.ch/LEPBOSC/.
[35] N. Uraltsev, hep-ph/0010328.
[36] The LEP V_{ub} working group, LEPVUB -00/01.

[37] CLEO collabration, hep-ex/9905056.
[38] W.Y. Wang, Y.L. Wu, Y.A. Yan, Int. J. Mod. Phys. **A15** 1817 (2000).
[39] Y.A Yan, Y.L. Wu, W.Y. Wang, Int .J. Mod. Phys. **A15** 2735 (2000).
[40] Y.L. Wu and Y.A. Yan, hep-ph/0002261, Int .J. Mod. Phys. **A16** 285 (2001).
[41] T. Draper, hep-lat/9810065. S. Sharpe, hep-lat/9811006. S. Aoki, et. al ,JLQCD Collab, Nucl. Phys. B (proc. suppl)63A-C281(1998).
[42] T. Draper,*Nucl.Phys.Proc.Suppl* 73(1999)43. S. Sharpe, hep-lat/9811006.
[43] Belle Collaboration, BELLE-CONF-0001.
[44] P.Checchia, E. Piotto, F. Simonetto, hep-ph/9907300.
[45] A. Ali and D. London, hep-ph/0012155.
[46] Y. L. Wu, hep-ph/0012371, to be published in Phys. Rev. D..
[47] F. James and M.Roos, Commpu.Phys.Comm, 10(1975)343
[48] N. G. Deshpande, X. G. He, W. S. Hou and S. Pavaska *Phys. Rev. Lett.* **82** (1999) 2240, X. G. He, W. S. Hou and K. C. Yang *Phys. Rev. Lett.* **83** (1999) 1100, W. S. Hou and K. C. Yang, *Phys. Rev.* **D61** (2000) 073014.
[49] Y. L. Wu and Y. F. Zhou, *Phys. Rev.* **D62** (2000) 036007,
Y. F. Zhou, Y. L. Wu, J. N. Ng and C. Q. Geng, *Phys. Rev.* **D63** (2001) 054011.
[50] L. F. Abbott, P. Sikivie and M. B. Wise, *Phys. Rev.* **D21** (1980) 1393.
[51] D. Atwood, L. Reina, and A. Soni, *Phys. Rev.* **D55** (1997) 3156.
[52] D. B. Chao, K. Cheung, and W. Y. Keung, *Phys. Rev.* **D59** (1999) 115006.
[53] A.J Buras, P. H. Chankowski, J. Rosiek and L. Slawianowska, hep-ph/0107048
[54] A. Ali and E. Lunghi, hep-ph/0105200.

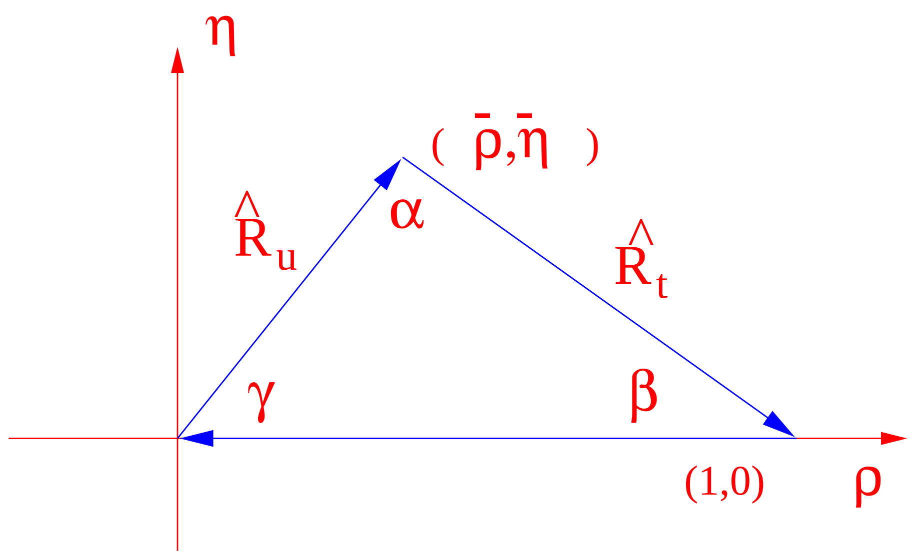

FIG. 1. The unitarity triangle

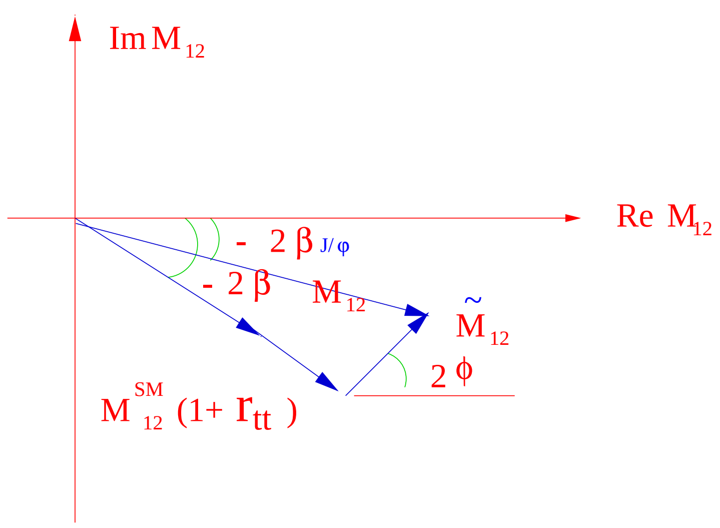

FIG. 2. The new physics contribution to M_{12}

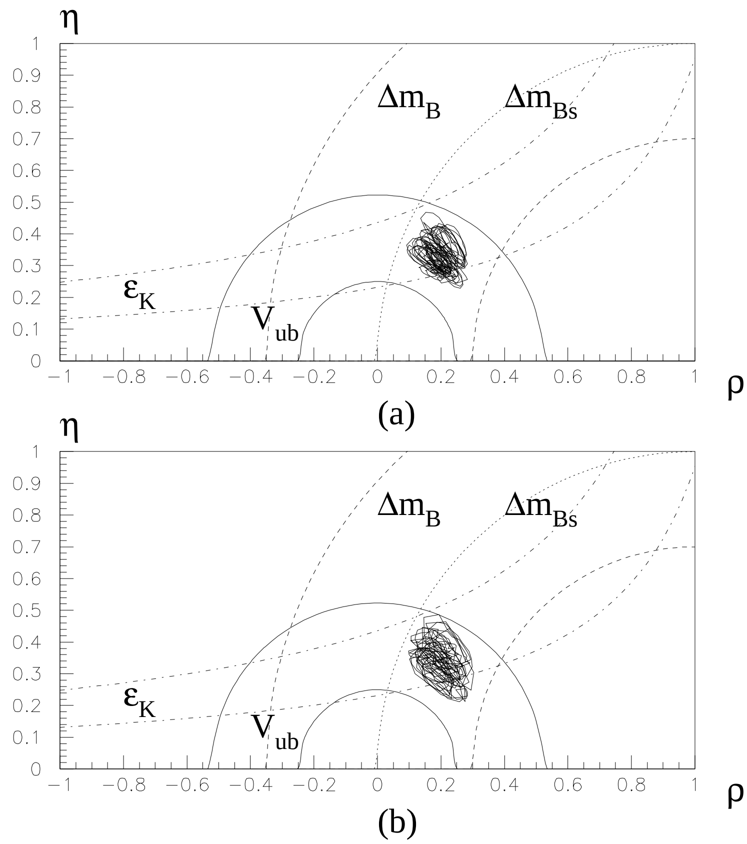

FIG. 3. The allowed region for ρ and η from the global fit at 68%CL (a) and 95%CL (b). The individual constraints from V_{ub}, ϵ_K and $B^0_{(s)} - \bar{B}^0_{(s)}$ are also shown.

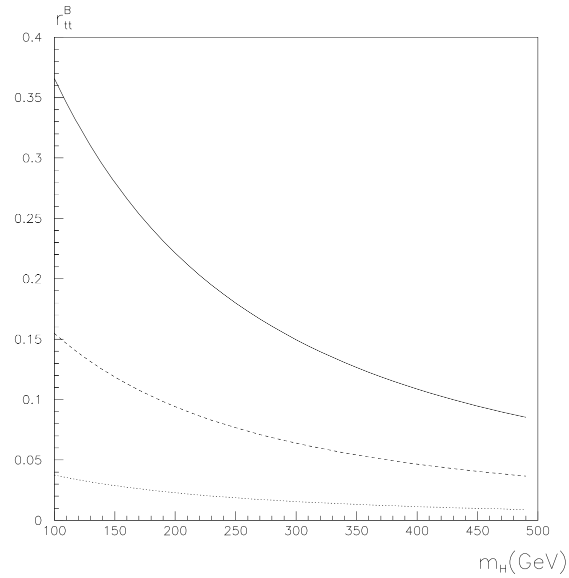

FIG. 4. r_{tt}^B as a function of the charge Higgs mass $m_{H^{\pm}}$. The three cures correspond to ξ_t=0.6(solid),0.4(dash),0.2(dotted) respectively.

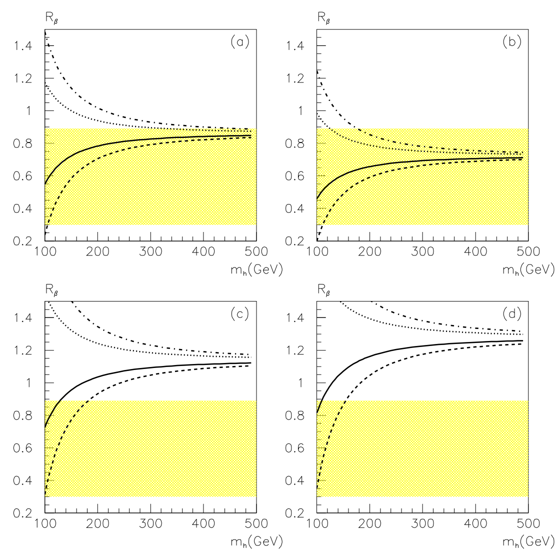

FIG. 5. R_β as a function of the mass of neutral Higgs mass m_h with different values of $Im(Y^d_{1,13})^2$ and $\tilde{\epsilon_K}/\epsilon_K$. The shadowed band indicates the allowed region for R_β at 68% CL.

(a) $Im(Y^d_{1,13})^2$=0.01(solid), 0.02 (dashed), -0.01 (dotted), -0.02 (dotted-dashed) with $|1-\tilde{\epsilon_K}/\epsilon_K| = 0.9$.

(b) The same as (a) with $|1-\tilde{\epsilon_K}/\epsilon_K| = 0.8$.

(c) The same as (a) with $|1-\tilde{\epsilon_K}/\epsilon_K| = 1.1$.

(d) The same as (a) with $|1-\tilde{\epsilon_K}/\epsilon_K| = 1.2$.